Notebook, N-07-06-17

07-06-17

Order Number 1939.

June 17, 1907.

Resistance Measurements
of
Thin Films of Metals Plated
on Glass by Convection Currents.

Section of film measured will be in each case $\frac{3}{4}$" wide and 1 inch long between contact terminals.

Contact terminals consist of heavy copper sheets cemented on glass with their edges parallel and exactly one inch apart. Three layers of tinfoil are clamped on top of these to form a cushion on which to lay the glass coated with metal. A weight is then placed on top of the glass.

## Apparatus.

Ordinary Post-Office Bridge connected up on Wheatstone principle with five storage cells and a D'Arsonval galvanometer.

Galvanometer is provided with a mirror which reflects a ray of light onto a scale at a radius of about 53 inches.

June 17, 1907.

Connected up a coil of known resistance to measure, and check up the bridge. Took following readings:—

1000 : 1000 = 84 : x

1000 : 100 = 963 : x

1000 : 10 = 7% balanced — Great variation of galvanometer when plugs are all in "C". This shows that 10 Ω coil on "B" is disconnected or broken. This bridge is Ty. G.

Readings on B bridge #2.

10 : 10 = 98 - : x
100 : 100 = 98 - : x
1000 : 1000 = 98 - : x
1000 : 100 = 979 : x
1000 : 10 = 9787 : x

Bridge #2 seems to be O.K.

June 18, 1907.

Connected a standard ohm up with about 2 feet of lamp cord. Results –

1000 : 110 = 102.5 : x

x = 1.025 Ω

Value is high because temperature is 24°C instead of 15° as prescribed and also on account of the lamp cord and contacts in circuit.

June 19, 1907.

Said brass copper strip, the same size as the glasses, across terminals to measure resistance of the connecting wires and contacts.

Results:—

With pressure of 335 grams

$1000 : 10 = 1.7 : x$

$x = .017\ \Omega$

With pressure of 1075 grams

$1000 : 10 = 1 : x$

$x = .01\ \Omega$

6/19/07.

J.A.I. # 7.

Platinum - $3\frac{3}{4}$ hrs. plating

Opaque film.

Plate # 1.

Pressure 335 grams

1000 : 10 = 506 : x

x = 5.06 ohms.

Plate # 2.

Pressure 335 grams.

1000 : 10 = 838 : x

x = 8.38 Ω

Plate # 3

Pressure 335 grams.

1000 : 10 = 705 : x

x = 7.05 Ω

Plate # 4.

Pressure 335 grams.

1000 : 10 = 1908 : x

x = 19.08 Ω

Hard to balance galvanometer. Resistance of contact between film + foil must vary.

6/10/07.

Platinum - 3 3/4 hrs. plating

Repeat previous test and also test using more pressure

Plate # 1.

Pressure 335 grams

1000 : 10 = 1800 : x

x = 18 ω

Did not disturb plate but tried again a few minutes later -

1000 : 10 = 870 : x

x = 8.7 ω

Kept key pressed down and adjusted galvanometer to 0 instead of taking instantaneous reading -

1000 : 10 = 859 : x

x = 8.59 ω

3 instantaneous reading few minutes later again -

1000 : 10 = 872 : x

x = 8.72 ω.

4/19/07.

Platinum - 3 1/4 hrs. plating

Plate #1.

Pressure 1152 grams
1000 : 10 = 630 : x
x = 6.3 w

Still hard to hydrometer gals-amounts. If key is held down gal. will apparently assume a constant position - not thus indicating it will oscillate vigorously for no evident reason.

Pressure 2127 grams
1000 : 10 = 598 : x
x = 5.98 w

Pressure 3267 grams
1000 : 10 = 565 : x
x = 5.65 w

These pressures gave fairly constant results.

6.22
8.19
6.46
6.53

4) 27.39

6.847 w average of values on opposite page for Platinum plated 3 3/4 hrs. (Momentary method)

Film is opaque.
Color is white but is tinged here and there with straw color.
Makes a perfect mirror.

6/19/07.

Platinum - 3 3/4 hrs. plating

Pressure in each case 2450 g.

Plate # 1.
Momentary current = 6.22 w
Continuous " = 6.00 w

Plate # 2.
Momentary current = 8.19 w
Continuous " = 8.40 w

Plate # 3.
Momentary current = 6.46 w
Continuous " = 7.36 w

Plate # 4.
Momentary current = 6.52 w
Continuous " = 6.50 w

Momentary current method is most convenient and values seem to be fairly constant so hereafter that method will be used.

6/19/07.

Platinum 1 mm² in section long 1 meter long, resistance = .0898 Ω

R of same section but 1 inch long = .0898 × .0254 = .00227892 Ω.

But R of film 1 inch long was found to be 6.847 Ω or 3001.85 times this value —

∴ The section area of the film is $\frac{1}{3001.85}$ = .0003331 mm²

Film is approximately $\frac{3}{4}$ inch wide or 19.05 mm.

∴ Its thickness would be $\frac{.0003331}{19.05}$ = .00001748 mm.

Or .00001748 × .03937 = .000000688 inches thick.

.0898
.0254
.35992
44960
17992

.00227892 ) 6.847 00000 | 3001.85
6 47276
4724000
2278092
19590080
18247360
1342720
1140460
202260

3001.85 ) 1.000000 | .0003331 mm²
900555
994450
900555
938950
900555
383950
300185

19.05 ) .0003331 | .00001748 mm
1905
14260
13335
9250
7620
16300
15240

.00001748
.03937
12236
52444
15732
5244
.000000688188 in.

Opaque film except at ends; a few scratches and symbols can be seen.

Color is minute-lined with straw color same as 3 3/4 hr. plate. Film on one side has mottled appearance.

June 20, 1907.

Platinum - 2 hrs. plating

J.A.T. # 8.

Pressure in each case 2450 g.

| | |
|---|---|
| Plate # 1. | 8.12 W |
| Plate # 2. | 14.65 W |
| Plate # 3. | 9.61 W |
| Plate # 4. | 10.62 W |
| | 4 / 43.00 |

Average - 10.75 W

6/20/07.

Platinum - 1 hr. plating.
J.A.T. # 9.

Pressure 2450 grams.

| | | |
|---|---|---|
| Plate # 1. | Front | 18.38 |
| | Back | 111.2 |
| Plate # 2. | Front | 29.63 |
| | Back | 52.23 |
| Plate # 3. | Front | 17.73 |
| | Back | 53.48 |
| Plate # 4. | Front | 24.48 |
| | Back | 63.01 |
| | 4 | 90.22 |
| Average | | 22.555 W |

These films are translucent.

# 1 has few pinholes
# 2 " many "
# 3 " long scratches & pinholes.
# 4 " pinholes

There is metal plated on both sides of glass of all the slides, but the back coating is very thin.

Will measure both sides hereafter so as to be sure of getting the right one.

Scales blank known by transmitted light.

These are very uniform films.

#1 - Very few pinholes.
2 - Perfect coating - no pinholes
3 - Very few pinholes.
4 - " " "

Film is just transparent.
Pinholes white-imaged with smoky blue by reflected light.
Pinholes blinds known by transmitted light.

6/20/07

Platinum - ½ hr plating
I.A.T. #10.

Pressure 24.50 grams.

| | | |
|---|---|---|
| Plate #1. | Front | 34.62 |
| | Back | 94.51 |
| Plate #2. | Front | 39.71 |
| | Back | 84.50 |
| Plate #3 | Front | 45.83 |
| | Back | 77.88 |
| Plate #4 | Front | 41.77 |
| | Back | 60.22 |
| | 4 | 160.88 |
| Average | | 40.22 W |

6/20/07.

Platinum - 15 min. plating
J.A.S. # 11.

Pressure 2450 g.

Plate #1. Front 140.
Back 137

Plate #2. Front 140.3
Back 170.8

Plate #3. Front 207.7
Back 445.4

Plate #4. Front 211.7
Back 158.4

4/703.7
Average 175.9 Ω

Very transparent films of great uniformity. All looked exactly alike. Colors same as ½ hr. film, only thinner. Repeated measurements on plate #3 three times and got practically the same result each time. For some reason it must have a heavier coating on the back than the others have.

6/20/07.

Platinum - 7½ min. plating
T.A.T. # 12.

Pressure 24.50 g.

Plate #1. Front 168.3
Back 33390

Plate #2. Front 140.2
Back 69990

Plate #3. Front 154.8
Back 515000

Plate #4 Front 134.8
Back 15040

4 | 601.1
Average 150.27

Very transparent.
Colors by reflected and transmitted light same as 15 min film only thinner.

A very slight coloration of the glass can barely be seen.

With resistances on bridge arranged to give highest possible measurement - i.e. 10 : 1100 = 10000 : x — galvanometer was still deflected to the low side.

The deflection in each case was 29 mm, which was found to be the same amount as when no connection was made across the contact terminals except thru the air and the glass support.

This shows that the resistance of the one minute platinum film is infinite.

June 21, 1907.

Platinum - 1 min. plating.
Dat. #13.

Pressure 2450 g.

Plate #1. Front } Greater than
Back } 1,100,000 ohms.

Plate #2. Front } Same
Back }

Plate #3. Front } Same
Back }

Plate #4. Front } Same
Back }

6/21/07.

Tabulated Results on Plottinum.
T.D.Z. #7 - 13.

All micrograd under pressure of 7450 atms.

Average taken of four plates in each case.

#7 Plated 3 7/4 hrs. Tooth Coating = 6.847 Ω
8 " 2 " " " 10.75
9 " 1 " " " 22.55
10 " 1/2 " " " 40.72
11 " 15 mins. " " 175.9
12 " 7 1/2 " " " 150,729
13 " 1 " " " Infinite

Opaque film
makes a perfect mirror.
Metal is visible by reflected light
but has blinds spots, markings
on the backs.

6/21/07.

Nickel - 4 hours plating.
Jar #2.

Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate #1 | 6.27 | 14.94 |
| Plate #2 | 4.96 | 15.76 |
| Plate #3 | 7.42 | 24.59 |
| Plate #4 | 6.87 | 25.02 |
| | 4 \| 25.52 | |
| Average | 6.38 | .0 |

Transparent.
Film looks brown by transmitted light.
By reflected light it is white just tinted with yellow.

6/21/07.

Nickel - 2 hrs. plating
J.A.I. # 3.

Pressure, 2450 grams.

| | Front | Back |
|---|---|---|
| Plate # 1. | 57.78 | 6545. |
| Plate # 2. | 52.98 | 249.8 |
| Plate # 3. | 48.16 | 1475. |
| Plate # 4 | 25.47 | 1900 |
| | 184.29 | |

Average = 46.07 W

6/21/07.

Nickel - 1 hr. plating
T.A.3. #4.

Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate #1. | 421.3 | 769.3 |
| Plate #2. | 115.3 | 233.1. |
| Plate #3. | 67.37 | 500.5 |
| Plate #4. | 139.6 | 298.7 |
| | 743.57 | |
| Average | 185.89 | ω |

6/21/07.

Nickel - $\frac{1}{2}$ hr. plating
I.D.2 = 5.

Pressure 2450 grams

| | Anvil | Rods |
|---|---|---|
| Plate #1. | 469.8 | 225000 |
| Plate #2. | 429.0 | 29,000 |
| Plate #3. | 341.9 | 1902 |
| Plate #4 | 357.2 | 154000 |

4 | 1597.9

Average 399.47 w

6/21/07

Nickel - 15 min. Plating
T.A.T. #6

Pressure 7450 approx

| | Front | Back |
|---|---|---|
| Plate #1. | 7157 | 0 on 1.000000 |
| Plate #2. | 7406 | " |
| Plate #3. | 4453 | " |
| Plate #4. | 4490 | " |
| | 4 \| 18496 | |
| Average | 4624 | " |

6/21/07.

Tabulated Results on Treated T.A.T. #2-6.

All measured under pressure of 2450 grams.

Averages of the four plates-

#2 Plotted 4 hrs. Trout Continuing = 6.332
3 " 2 " " " = 46.07
4 " 1 " " " = 195.89
5 " ½ " " " = 399.47
6 " ¼ " " " = 4674.0

June 24, 1907.

Copper - 4 hrs. plating.
Exp. #14.

Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate #1 | .585 | .87 |
| Plate #2 | .39 | .515 |
| Plate #3 | .315 | .46 |
| Plate #4 | .507 | .775 |
| 4 | 1.797 | |
| Average | .449 Ω | |

Films are all more or less oxidized.

Film on front is pinkish violet - but it is not oxidized right down to the glass as a patch of pure copper color shows thru the glass from the back.

Film is opaque.

6/24/07.

All more or less oxidized.
Translucent.
Scale: pinkish violet by reflected light + greenish black by transmitted light. Vari-colored bands on backs.
Plate #2 is not oxidized as badly on the edges and backs, reddish violet by transmitted light.
All the plates have pinholes and #3 + #4 are scratched badly.

Copper - 2 hrs. plating.
Exp. #15.

Pressure - 2450 grams

| | Front | Back |
|---|---|---|
| Plate #1. | 16.48 | 0mm 1000.000 |
| Plate #2. | 7.21 | " |
| Plate #3. | 11.76 | " |
| Plate #4. | 12.79 | " |
| | 4)48.24 | |
| Average | 12.06 | " |

June 25, 1907.

Copper - 1 hr. plating.
Exp. # 16.

Pressure - 7450 grams.

| | Front | Back |
|---|---|---|
| Plate #1. | 0.00001000000. | 0.00001000000 |
| Plate #2. | " | " |
| Plate #3. | " | " |
| Plate #4. | " | " |

Front and back in each case measured more than 1,000,000 ohms.

Transparent films.

As seen by reflected light, films have a complex coloring. There is some bright yellow on the edges and pale blue with traces of red in the center. There is also a tinge of green where the yellow merges into the blue.

By transmitted light the main part of the film looks greenish yellow and the edges brownish yellow.

There are some scratches and pinholes on all of these and #3 has a mottled appearance.

6/25/07.

Films are transparent but not so much as the first one, however set. This is because they are oxidized more than the first ones.

By reflected light one side of plate appears barely uniform bluish blue with a border of yellow, red, blue + green. This is probably the back side. The other side is very beautiful. It has a little yellow in the center - then comes the main part which is red. This has a border all around consisting of blue merging into green and then yellow again.

By transmitted light, center of plate is yellowish green and edge is pure yellow.

Copper - 1 hr. plating
Exp. # 17.

Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate # 1. | Ohm 1.000.000. | Ohm 1.000.000 |
| Plate # 2. | " | " |
| Plate # 3. | " | " |
| Plate # 4. | " | " |

Front and back in each case measured more than 1.000.000 ohms.

6/25/07.

Transparent films not quite as heavy as #17.

By reflected light the colors of the front and back correspond to those of #17 only they are in no regular order from center to edge but are very much mixed up. Blue seems to predominate rather than red and the film has a heterogeneous, mottled appearance.

By transmitted light film is greenish yellow with blotches of green in central part.

Could see no difference between #4, which had comparatively low resistance, and the others except that it is perhaps more mottled.

Copper - 1 hr. plating.
Exp. # 18.

Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate #1. | 19500 | Over 1000000 |
| Plate #2. | 884000 | " |
| Plate #3. | Over 1.000.000 | " |
| Plate #4. | 57,35 | " |
| | 4 \| 1,902557,35 | |
| Average | 475639,33 | " |

Very transparent.
Looks a very pale blue with tinges of straw color by reflected light.
Scarcely any color can be seen by strong transmitted light but if plate is laid on white paper it is seen to have a delicate yellow color with just a suggestion of green.

6/25/07.

Copper - ½ hr. plating
Exp. # 19.

Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate # 1. | Over 1000 000. | Over 1000 000. |
| Plate # 2. | " | " |
| Plate # 3. | " | " |
| Plate # 4. | " | " |

6/25/07.

Copper – $\frac{1}{2}$ hr. plating.
Exp. # 20.

Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate # 1. | 731.3 | Over 1000.000 |
| Plate # 2. | 540.9 | " |
| Plate # 3. | 192.8 | " |
| Plate # 4. | 343.0 | " |
| 4 | 1809.5 | |
| Average | 452.1 | W. |

Film blue tinged with yellow by reflected light.
When laid on white paper it appears blemish green with tinges of yellow.
Very transparent but not so much so as # 19 on account of the different color.

6/25/07.

Copper - ½ hr. plating
Expo. # 21

Very transparent and clear. Mystery blue by reflected light. When laid on white paper it appears pale orange in color.

Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate # 1. | Over 1000.000. | Over 1.000.000 |
| Plate # 2. | " | " |
| Plate # 3. | " | " |
| Plate # 4. | " | " |

June 26, 1907.

Tabulated Results on Copper
Exp. #14 - 21.

Contact Pressure 2450 grams.

Each figure is the average of four plates - front coating.

| | | |
|---|---|---|
| #14. | Plated 4 hrs. | .449 Ω |
| 15. | " 2 " | 12.06 " |
| 16. | " 1 " | Infinite |
| 17. | " " " | " |
| 18. | " " " | 49,563,933 " |
| 19. | " ½ " | Infinite |
| 20. | " " " | 457.1 " |
| 21. | " " " | Infinite |

The different degrees of oxidation of the copper probably accounts for these irregular results.

Transmitted

By reflected light the film is white but is stained considerably with brown, especially on the front.

By transmitted light the color is brownish blue.

6/26/07.

Bismuth — 1 hr. plating.

Exp. #24.

Contact Pressure 2450. grams.

| | Front | Back |
|---|---|---|
| Plate #1. | 329.0 | 342.3 |
| Plate #2. | 306.7 | 698.2 |
| Plate #3 | 317.6 | 432.8 |
| Plate #4. | 263.0 | 479.5 |

4 | 1306.3

Average 326.57 Ω

6/26/07.

Bismuth – ½ hr plating.
Exp. # 25.

Contact Pressure 7450 grams.

| | Front | Back |
|---|---|---|
| Plate # 1. | Over 1000000. | Over 1000000. |
| Plate # 2. | " | " |
| Plate # 3. | " | " |
| Plate # 4. | " | " |

Transparent
Both sides look blinish brown by reflected light.
Looks blackish blue by transmitted light.

Looks like clear white glass but a closer examination reveals a very delicate blinish white film.

6/26/09.

Brannolite + Au. plating.
Exp. #26.

Contact Pressure 7450 grams.

| | Front | Back |
|---|---|---|
| Plate #1 | Over 1000.000. | Over 1000.000 |
| Plate #2 | " | " |
| Plate #3 | " | " |
| Plate #4 | " | " |

6/26/07.

Results on Bismuth
Exp. # 24 - 26.

Contact Pressure 2450 grams.

Average for the four plates of each set - front loading.

| | | | |
|---|---|---|---|
| 1 | #24 | Plated 1 hr. | 326.57 Ω |
| | 25 | " ½ " | Infinite |
| | 26 | " ¼ " | " |

Film is transparent.
Film has tints of blue & yellow by reflected light and looks reddish brown by transmitted light.

6/26/07.

Immersion - 12 hrs. plotting
Exp. = 73.

Contact Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate #1. | 575.8 | 440500 |
| Plate #2. | 415.0 | 28770 |
| Plate #3. | 414.5 | 19390 |
| Plate #4. | 330.6 | 45000 |

4 | 1735.9

Average 433.97 W

Transparent film.
By reflected light, film has an even pale blue tint on both sides.

By transmitted light it is a muddy brown color.

6/26/07.

Tungsten - 4 hrs. platinum.
Exp. 32.

Contact Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate #1. | 995.5 | Over 1000.000 |
| Plate #2. | 826.6 | 935.000 |
| Plate #3. | 664.7 | 148400 |
| Plate #4. | 887.6 | Over 1000.000 |
| 4 | 3364.4 | |
| Average | 841.1 | W. |

Radium Effect.

June 27, 1907.

Platinum 3¾ hrs. Plate #1. Reg. Press.
R by closed Circuit Method 5.00 Ω
Kept amtide closed and brought tube of Radium beneath the glass support and about ½ inch below the metallic film. It did not affect the balance of the galvanometer.

Platinum 1 hr Plate #1. Reg. Press.
R by closed Circuit Method 21.50 Ω
Subjected to influence of Radium as above with no effect on resistance.

Platinum 15 min. Plate #1. Reg. Press.
R by closed Circuit Method 149.8 Ω
Resistance unaffected by Radium emanations.

6/27/07.

Nickel 2 hrs. Plate #1. Reg. Press.
R by Closed Circuit Method 69,9 ω
Subjected to influence of Radium
as Platinum was subjected be-
fore, and found that conduct-
ivity of the Nickel remained
unchanged.

Copper 2 hrs. Plate #1. Reg. Press.
R by Closed Circuit Method 15.78 ω
Conductivity unaffected by
influence of Radium.

Bismuth 1 hr. Plate #1. Reg. Press.
R by Closed Circuit Method 730 ω
Conductivity unaffected by
influence of Radium.

Tungsten, 12 hrs. Plate #1. Reg. Press.
R by Closed Circuit Method 331. ω
Conductivity unaffected by
influence of Radium.

June 28, 1907.

Focused a direct vision spectroscope on an acetylene flame to get a continuous spectrum, and then placed transparent films of various metals in front of slit to see if they gave any absorption lines. Results —

Platinum.
Dim white spectrum. No dark lines visible.

Nickel.
Same as above.

Copper.
Same

Bismuth.
Same

Tungsten.
Same

Transparent Film

By reflected light film looks brown in center of plate and bluish gray at the edges.

By transmitted light it is light brown in center and dark brown at the edges.

June 29, 1907.

Resistance Measurement.

Iron - 12 hrs. plating.

Exp. # 27.

Contact Pressure - 2450 grams.

| | Front | Back |
|---|---|---|
| Plate # 1. | 614.8 | 1349.0 |
| Plate # 2. | 935.0 | 919.0 |
| Plate # 3. | 1328.0 | 569.1 |
| Plate # 4. | 928.0 | 1112 |
| 4 | 3705.8 | |
| Average | 926.4 | ω |

6/29/07.

White by reflected light
Yellow on very fine mirror.
3 dm is just translucent to strong light.
Color by transmitted light is spruce blue.

Resistance Measurement.
Silver - 45 min. plating.
3 x/a = 28.
Contact Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate #1 | 1.63 | 11.88 |
| Plate #2 | 2.18 | 7.05 |
| Plate #3 | 1.62 | 3.63 |
| Plate #4 | 1.43 | 12.29 |
| 4 | 6.86 | |
| Average | 1.715 Ω | |

July 1, 1907.

Effect of Magnetism on Resistance.

Used the large electromagnet across the 120 volt line, making a very strong field. Spread pole pieces as far apart as they would go (about 2¼"), and laid the contact plate on a sheet of mica on top of the poles so that the metal film would come over the gaps.

Had to use heavy lamp cord to connect from terminals to bridge.

Resistance of wires and contacts with a piece of copper, under pressure of 7535 grams, short-circuiting terminals, was .024 Ω. This value was unaffected by magnetism.

For accurate work this amount should be subtracted from the values given in the following pages.

7/1/07.

Effect of Magnetism on Resistance & Contact Pressure 2535 grams.

Iridium.

4 In. - Plate #1.

Resistance 5.35 Ω. Very slightly affected by magnetic field - not enough to measure. If contact key is held down while galvanometer balanced, and magnetizing current suitable is closed, galvanometer will be deflected about 10 mm to the low side showing that resistance of Ir is increased slightly in a magnetic field. When field is thrown off again with contact key still down, galvanometer does not swing back to zero immediately but comes rather slowly.

2 In. - Plate #1.

Resistance 39.61 Ω.

The resistance of this plate did not seem to be affected in

7/1/07.

the least by magnetism. Galvanometer balance was not disturbed appreciably when current was switched on and off thru field coils.

1 In. Plate "1." 7μ
Resistance 306.2 Ω
Resistance remains the same in the magnetic field – same result as with the 2 In. plating

½ In. Plate "1." 7μ
Resistance 389. Ω – Unaffected by magnetism.

Repeated experiment on the 4 In. plating and got same result as before i.e. – resistance was slightly higher in the field. – This result was obtained with the magnetic lines of force running lengthwise of the film that is, parallel with the current.

7/1/07.

Now tried the same Nickel film with the lines of force running across the film or perpendicular to the current. Result – the resistance was not affected by magnetism running in this direction.

Also on the same film tried the effect of reversing the direction of the magnetic flux with respect to the flow of current thru the film – makes the lines of force more parallel to the current as originally. Result – the deflection of the galvanometer was to the low side as before, showing that the resistance of the film was slightly increased when the film was traversed lengthwise by magnetic lines in either direction, and that the resistance was unaffected by magnetic lines traversing it crosswise.

7/1/07.

Platinum. 3 3/4 lns. Plate #1.
Resistance 7.3 Ω. Unaffected by magnetic flux in either direction.

Platinum. 2 lns. Plate #1.
Resistance 8.68 Ω. Unaffected by magnetic flux in either direction.

Platinum. 1/2 ln. Plate #1.
Resistance 28.48 Ω. Unaffected by magnetic flux in either direction.

Copper. 4 lns. Plate #1.
Resistance .66 Ω. Unaffected by magnetic flux in either direction.

Copper. 2 lns. Plate #1.
Resistance 10.90 Ω. Unaffected by magnetic flux in either direction.

7/1/07.

Tungsten. 12 lns. Plate #1.
Resistance 378.4 Ω. Unaffected by magnetic flux in either direction.

Tungsten. 4 lns. Plate #1.
Resistance 1331 Ω. Unaffected by magnetic flux in either direction.

Bismuth. 1 ln. Plate #1.
Resistance 348.7 Ω. Unaffected by magnetic flux in either direction.

Iron. 12 lns. Plate #1.
Resistance 1281 Ω. Unaffected by magnetic flux in either direction.

Silver 45 mins. Plate #1.
Resistance 2.79 Ω. Unaffected by magnetic flux in either direction.

July 3, 1907.

Absorption Spectra.

Silver. 45 min. Plate #1.

This is the one that looks deep blue by transmitted light.

Film is too dense to pass a bright spectrum when it is interposed between slit and flame. A little red and orange shows up dimly. Hardly any yellow shows but green and blue are quite bright. Violet can just be made out.

No dark lines are visible.

Plates #2, 3, & 4 corresponded with plate #1.

---

Silver. 22 min.

Film is quite thin and when one plate only was interposed, spectrum was just dimmed very slightly. Two plates increased the effect

7/3/97

and the yellow seemed to be absorbed more than the other colors. No dark lines were visible.

Silver. 11 min.
Three plates interposed at once merely dimmed the whole spectrum. No dark lines.

Silver. 5 min.
Four plates interposed merely dim the whole spectrum.

Silver. 30 min.
Sodas blue by transmitted light but could not make out any absorption effects with the spectroscope. All the colors were dimmed uniformly.

7/3/07.

The metals tried for absorption spectra on June 28th, I now tried over again using thicker films - as the results obtained then were on the thinner plates.

Metals tried were -

Nickel
Platinum
Copper
Tungsten
Bismuth
Iron

There was no change in the results, i.e. - they all dimmed the whole spectrum without respect to the colors. Even the copper films which were some of them highly colored when viewed by transmitted light showed no appreciable selective absorptions.

See next page.

July 5, 1907.

Resistance Measurement.

Silver. 22 min. plating.
Exp. # 29.
Contact Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate # 1. | Ohm 1.000.000. | Ohm 1.000.000. |
| Plate # 2. | " | " |
| Plate # 3. | " | " |
| Plate # 4. | " | " |

Deposit rubs off very easily. Plate #1 was scratched considerably by brushing with a camel-hair brush.

By reflected light, color is white tinted with blue, pink, + yellow. Pinkish-browns by transmitted light.

Pale blue, pink and straw-color by reflected light.

By transmitted light color is greenish blue in thinner parts and pinkish brown in thicker parts of film.

Same colors as #30 by reflected and transmitted light easily thinner.

7/5/07

Resistance Continued.

Silver. 22 min plating.
Exp. #29.
Contact Pressure 2450 grams.
Front and back coatings of all four plates measure more than 1,000,000 ohms.

Silver. 11 min plating.
Exp. #30
Contact Pressure 2450 grams.
Front and back coatings of all four plates measure more than 1,000,000 Ω.

Silver. 5 min plating.
Exp #31
Contact Pressure 2450 grams.
Front and back coatings of all four plates measure more than 1,000,000 Ω.

By reflected light, film is white with slight images of blue and violet.
By transmitted light it is blue and violet.
Transparent Film.

7/5/07.

Resistance Continued.

Silver. 30 mm platinum.
Exp. #32.
Contact Pressure 2450 grams.

| | Front | Back |
|---|---|---|
| Plate #1. | 9.49 Ω | Ωm 1000.000. |
| Plate #2. | 5.67 | " |
| Plate #3. | 9.71 | " |
| Plate #4. | 111.3 | " |

Average of Plates #1, 2, & 3 = 8.29 Ω

By reflected light film is straw color with images of blue and pink.
By transmitted light film is blue and violet.

By reflected light film is straw color with here and there a small blue spot.
By transmitted light film is blue and the same spots are yellowish.

7/5/07.

Resistance Continued.

Silver. 5 min. plating - after current was passed for 1 hr to get rid of all traces of oxygen. Exp. # 33.
Single slide was placed in middle of tube. Rubbed the deposit off of the edges so as to disconnect the two sides. Resistance, using usual contact pressure of 2450 grams, then was -

One Side 19.43 Ω.

Other Side 21.39 Ω.

Silver. 2 min. plating after sparking free of oxygen as above. Exp. # 34.
Contact pressure 2450 grams.
Both films have more than 1000000 ohms resistance.

7/5/07.

Effect of Magnetism on R.

Had a brass clamp made to press plates on contact terminals, instead of using nickels, so that film could lie just between the poles of magnet adjuster – that is, so that the plane of the film is perpendicular to the magnetic lines of force. Pole pieces of magnet are about one inch apart.

Contact pressure is unknown but it is the same for both readings on the same film.

Nickel. 4 hrs. Plate #1.
Resistance 5.07 Ω. Decreased a very little in magnetic field – less than .01 Ohm.

Nickel. 2 hrs. Plate #1.
Resistance 7.08 Ω. Decreased to 7.104 Ω in magnetic field on first trial but on two subsequent trials it remained at 7.08 Ω both in field and out.

7/5/07.

Platinum. $3\frac{3}{4}$ hrs. Plate #1.
Resistance 4.54 Ω. Unaffected
by magnetic flux.

Copper. 2 hrs. Plate #1.
Resistance 33.95 Ω Unaffected
by magnetic flux.

Tungsten. 12 hrs. Plate #1.
Resistance 446.5 Ω. Unaffected
by magnetic flux.

Bismuth. 1 hr. Plate #1.
Resistance 406.0 Ω Unaffected
by magnetic flux.

Iron. 12 hrs. 1206 Ω.
Silver $\frac{3}{4}$ " 2.06 Ω.
Conductivity of both is
unaffected by magnetic
flux.

July 10, 1907.

Resistance Measurement.
Silver Films - Plotted for different lengths of time after first sparking tube for about an hour to combine all traces of oxygen. Purified hydrogen was in tube as usual.
Contact pressure on each coil will be 2450 grams.

Silver. 5 mins. Exp. = 33.

| | | | |
|---|---|---|---|
| One side | 9.27 | ω | 20.74 |
| Other " | 37.26 | ω | |

Silver. 4 mins. Exp. = 39.

| | | | |
|---|---|---|---|
| One side | 44.48 | ω | 180.14 |
| Other side | 315.8 | ω | |

Silver 3 mins. Exp. = 40.

| | | | |
|---|---|---|---|
| One side | 38.51 | ω | 532.75 |
| Other " | 1077 | ω | |

By transmitted light the 5, 4 and 3 minute Silver films are blue, the 2 and 1 minute films are blue and yellow, and the ½ min films are mostly yellow. The yellow color varies from a pinkish yellow to straw color.

By reflected light the colors are just reversed i.e. the blue films look straw color and the yellow films look blue.

Silver 2 min # 34.
Both sides over 1.000.000 Ω.

Silver 1 min # 35.
Both sides over 1.000.000 Ω.

Silver ½ min # 36.
Both sides over 1.000.000 Ω.

Silver ½ min # 37.
Both sides over 1.000.000 Ω.

Silver ½ min # 38.
Both sides over 1.000.000 Ω.

July 15, 1907.

Effect of Temperature on Resistance.

The plate carrying the metal film is laid on a small piece of plate glass, and brass contact clamps are adjusted and fastened so that there is an inch of the film between the contact edges. The whole thing is then immersed in a bottle of paraffin oil for the measurements.

The temperature of the bath will be maintained at each point five minutes before taking the measurement of resistance.

Platinum. 3 3/4 hrs. Plate #3.

Measured resistance in air at 24° C. - which was 4.08 Ω. Then immersed in oil at same temp. and measured again. It then was 4.07 Ω - showing that the oil is a good insulator.

7/15/07.

Platinum. 3¾ hrs. cont'd.

Resistance at different temperatures was found to be as follows —

| TEMP °C. | RESISTANCE. |
|---|---|
| 25° | 4.06 Ω |
| 41 | 4.19 |
| 60 | 4.20 |
| 80 | 4.31 |
| 100 | 4.37 |
| 120 | 4.43 |
| O₂-bottle was opened slightly here. | |
| 140 | 4.42 |
| 160 | 4.46 |
| 180 | 4.76 |
| 200 | 4.19 |

July 16, 1907. Ultrafilm - platinum - 3 1/2 mm

Oil-bath containing film and contact pieces, was left to cool off last night. The connections were not disturbed.

Will now repeat yesterdays test and also take measurements going back down from 200° to normal -

| Temp. °C. | Resistance |
|---|---|
| 23° | 3.66 Ω |
| 40 | 3.74 |
| 60 | 3.80 |
| 80 | 3.87 |
| 100 | 3.91 |
| 120 | 3.98 |
| 140 | 4.04 |
| 160 | 4.10 |
| 180 | 4.17 |
| 200 | 4.22 |
| 180 | 4.13 |
| 160 | 4.05 |
| 140 | 3.98 |
| 120 | 3.91 |

Temp. - Resistance Curve, cont'd.

| TEMP. °C. | RESISTANCE. |
|---|---|
| 100° | 3.86 Ω |
| 80 | 3.80 |
| 60 | 3.74 |
| 50 | 3.715 |
| 40 | 3.69 |
| 27 | 3.665 |

Increase in resistance for 160° rise in temperature (40° - 200°) is 4.22 - 3.74 = .48 Ω or 12.8 %.

The temperature coefficient of platinum according to these figures would therefore be .0008 per degree C. This is much lower than the value usually given. Dewar & Fleming give .00367 for Platinum and Matthiessen gives .00247.

July 17, 1907.

Temperature - Resistance Curve

Platinum - 3 3/4 lns.

Same film that was used yesterday and the day before.

Connections have not been disturbed.

| TEMP. °C. | RESISTANCE. |
|---|---|
| 23.5° | 3.66 ω |
| 40 | 3.74 |
| 60 | 3.84 |
| 80 | 3.89 |
| 100 | 3.96 |
| 120 | 4.02 |
| 140 | 4.09 |
| 160 | 4.13 |
| 180 | 4.17 |
| x 200 | 4.21 |
| 180 | 4.13 |
| 160 | 4.05 |
| 140 | 3.99 |
| 120 | 3.94 |
| 100 | 3.88 |

Temp.-Resistance Curve, cont'd.

| TEMP. °C. | RESISTANCE |
|---|---|
| 80° | 3.92 Ω |
| 60 | 3.96 |
| 40 | 3.69 |

Very humid day. — Moisture may cause errors in readings.

These films are not plotted evenly on the glass. On most of them the metal is deposited the most heavily near one edge and thins down gradually toward the other edge.

By transmitted light the thicker parts of all the films are green, which becomes a yellowish green as the film thins down and finally pale blue in the very thin parts. The plotted films of the 1 and 3 minute films are nearly all blue.

By reflected light, films look salmon-pink shading into purple in the thin parts, from the front; and dull gold color, having a burnt appearance in the thin parts when viewed from the glass at the back.

7 | 17 | 07.

Resistance Measurement.

Contact Pressure 7450 grams.

Gold. 5 min. Plating.
Exp. #42
Thick Plate 11.94 Ω
Thin " 18.50 "

Gold. 4 min. Exp. #43.
Thick Plate 16.68
Thin " 68.95

Gold 3 min. Exp. #44.
Thick Plate 145.1
Thin " 305000

Gold 2 min Exp. #45.
Thick Plate 22.30
Thin " 127.6

Gold 1 min Exp. #46.
Thick Plate 190.7
Thin " Over 1,000,000

July 18, 1907.

Temperature-Resistance Curve.

Platinum - 3 3/4 hrs.

Same film that has been used before for this test.

Temperature will now be kept at each point 15 minutes before taking the resistance measurement, instead of 5 minutes as formerly.

| TEMP. °C. | RESISTANCE. | |
|---|---|---|
| 25° | 3.655 ω. | |
| 40 | 3.76 | |
| 60 | 3.84 | |
| 80 | 3.90 | |
| 100 | 3.97 | |
| 120 | 4.05 | |
| 140 | 4.11 | |
| 160 | 4.17 | ← Both zeroed by trolley on second thermometer |
| 180 | 4.19 | fall apparent contact |
| 200 | 4.22 | |
| 180 | 4.09 | |
| 160 | 4.04 | |

7/18/07.

Transp. - Resistance Curve, cont'd

| TEMP. °C. | RESISTANCE |
|---|---|
| 140° | 3.98 Ω |
| 120 | 3.93 |
| 100 | 3.89 |
| 80 | 3.84 |
| 25 | 3.70 |

These films were tested before for resistance on July 17th which was a very sticky, hot day. The air is dry to-day and the resistance of all but one film is higher.

Glass is hygroscopic and the metals may be, so that the humidity of the atmosphere possibly affects the results.

July 19, 1907.

Resistance Measurements.

Contact Pressure 2450 grams.

Gold. 5 min. 3 x/p. "42.
Thick Plate 113.58 ω
Thin " 29.62

Gold. 4 min. 3 x/p. "43.
Thick Plate 17.71
Thin " 79.98

Gold. 3 min. 3 x/p. "44.
Thick Plate 618.0
Thin " Over 1.000.000

Gold. 2 min. 3 x/p. "45.
Thick Plate 60.45
Thin " 791.7

Gold. 1 min. 3 x/p. "46.
Thick Plate 94.72
Thin " Over 1.000.000

7/19/07.

Thick plate is opaque in parts. Thin plate is translucent. Deep blueish green by transmitted light. Pure gold color from either side by reflected light.

Transparent.

Coatings are not as heavy as the 12 hr. platings of Fe ("72) done in the old way without sparking, free of oxygen.

By transmitted light color is gray with small yellow spots here and there and numerous pinholes.

By reflected light. Thin film is gray and thick film is brownish gray. Both have white markings extending up from the lower corners.

Resistance Measurements, cont'd.

Gold. Exp. #47.
30 minutes plating after sparking tube one hour.

| | | |
|---|---|---|
| Thick Plate | 1.48 | Ω |
| Thin " | 1.91 | |

Iron. Exp. #41.
15 hrs. plate after sparking tube one hour.

| | | |
|---|---|---|
| Thick Plate | 725.6 | Ω |
| Thin " | 554.0 | |

Put thick Fe plate in the brass clamps to try effect of magnetism. Resistance in clamps 511.1 Ω.
Resistance unaffected by magnetic lines passing thru film in any of the three directions.

July 25, 1907.

Resistance Measurements.

Contact Pressure 2450 grams.
Tube exhausted free of O before starting the platinum.

Platinum. 5 min. Exp. = 48.
Single Plate 71.53 ω
Film " 235.00

Platinum. 4 min. Exp. = 49.
Single Plate 261.4 ω
Film " 1911.0

Platinum. 3 min. Exp. = 50.
Single Plate 107.1 ω
Film " 350.2

Platinum. 2 min. Exp. = 51.
Single Plate 3588.0 ω
Film " 51950.0

Platinum. 1 min. Exp. = 52.
Single Plate Over 1.000.000
Film " " "

The 3 minute films look to be nearly the same thickness.

July 26, 1907.

Temperature-Resistance Curve.

Same apparatus that was used in making this test on the $3\frac{3}{4}$ in. Platinum film. (See under query 15.)
Temperature kept at each point 5 minutes before taking the resistance readings.

Gold. 30 min. Thick Plate. Exp. #4.

| TEMP. °C. | RESISTANCE |
|---|---|
| 25.8° | .827 |
| 40 | .852 |
| 60 | .88 |
| 80 | .91 |
| 100 | .942 |
| 120 | .96 |
| 140 | 1.00 |
| 160 | .96 |
| 180 | 1.175 |
| x 200 | Ohm 1000000 |
| 180 | " " |

See note on next page over.

On taking film plate out of contact clamps, found that the gold was completely removed at each end where the tinfoil made contact with it - this being the cause of the enormous rise in resistance.

No gold can be seen on the surface of the tinfoil, but it appears to have alloyed with the foil.

| Temp. °C. | Resistance |
|---|---|
| 140° | Over 1.000000 |
| 140 | " " |
| 120 | " " |
| 100 | " " |
| 90 | " " |
| 60 | " " |
| 40 | " " |
| 21.5 | " " |

Increase in resistance for 100° rise in temperature (40° - 140°) is 15 or 17.6 %.

This would make the temperature coefficient of gold .0176 per degree Centigrade.

Platinum gives it as .00365 per degree Centigrade.

Took plate out of contact clamps after this test and found that all lead gotten in between the silver and the foil.

The exposed part of the film between the contacts has changed color. It is now yellowish brown by transmitted light. By reflected light it looks white from the front side and blue from the back side. There is a sharp black line on the front of film where the edge of the foil came.

The ends of the film which were under the clamps have not changed color, i.e. - they are blue by transmitted light and white by reflected light.

July 29, 1907.

Temperature - Resistance Curve.

Temperature kept at each point five minutes before taking the reading.

Silver. 45 mm. Exp. #28. Plate "I".

| | TEMP. °C. | RESISTANCE. |
|---|---|---|
| | 22.2° | 1.594 ω |
| | 40 | 1.61 |
| | 60 | 1.632 |
| | 80 | 1.66 |
| | 100 | 1.72 |
| | 120 | 1.84 |
| | 140 | 1.97 |
| | 160 | 2.05 |
| | 190 | 2.25 |
| x | 200 | 3.71 |
| | 180 | 4.47 |
| | 160 | 5.14 |
| | 140 | 6.04 |
| | 120 | 6.18 |
| | 23 | 6.14 |

July 30, 1907.

Temperature-Resistance Curve.

Temperature kept at each point five minutes.

Platinum 3 3/4 hrs.

Exp. 7. Plate 1.

| TEMP. °C. | RESISTANCE. |
|---|---|
| 24° | 4.94 ω |
| 40 | 4.96 |
| 60 | 5.05 |
| 80 | 5.17 |
| 100 | 5.36 |
| 120 | 5.51 |
| 140 | 5.75 |
| 160 | 5.62 |
| 180 | 5.24 |
| × 200 | 5.28 |
| 160 | 5.10 |
| 100 | 4.95 |
| 60 | 4.78 |
| 33 | 4.60 |
| 22.2 | 4.56 |

July 31, 1907.

Temperature-Resistance Curve.

Platinum 37 hrs. Exp. #7. Plate #1.

Increase in resistance for 100° rise in temperature (40° - 140°) is .423 Ω or 9.14 %.

Temperature Coefficient would therefore be .000914 per degree C. - corresponding pretty closely to the value found on the first Platinum film on July 16th, which was .0008 per degree C.

These values are only about one-third of the value usually given for Platinum wire.

Test repeated same as yesterday. Connections have not been disturbed.

| Temp. °C. | Resistance. |
|---|---|
| 25.3° | 4.57 Ω. |
| 40 | 4.627 |
| 60 | 4.703 |
| 80 | 4.779 |
| 100 | 4.976 |
| 120 | 4.996 |
| 140 | 5.105 |
| 160 | 5.172 |
| 180 | 5.116 |
| × 200 | 5.170 |
| 180 | 5.111 |
| 160 | → Not Constant |
| 140 | 5.104 |
| 120 | 4.996 |
| 100 | 4.899 |
| 80 | 4.790 |
| 61 | 4.703 |
| 22 | 4.595 |

Resistance Data on Some of the Metals. From Mattlieven and Others.

Ohms per Mil-Foot at 0°C.

| | |
|---|---|
| Aluminum | 17.4 |
| Antimony | 211 |
| Bismuth | 730 |
| Cadmium | 60 |
| Cobalt | |
| Copper | 9.5 |
| Gold | 12.3 |
| Iron | 54.5 |
| Lead | 117 |
| Magnesium | 26.2 |
| Mercury | 546 |
| Nickel | 74.4 |
| Palladium | 61.1 |
| Platinum | 54 |
| Silver | 8.94 |
| Tellurium | 106 |
| Tin | 78.5 |
| Titanium | |
| Tungsten | |
| Zinc | 34.8 |